Effects of Concrete-Representational-Abstract Strategy on Mathematics Achievement of Pupils with Dyscalculia in Yenagoa Metropolis of Bayelsa State

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Abstract

The study explored "the effects of concrete representational abstract strategy on pupils' achievement with dyscalculia in the Yenagoa metropolis of Bayelsa State." The study adopted a "pre-test and post-test control group quasi-experimental design." Ninety-eight students were selected to participate in this study through a purposive sampling technique. Four intact classes from four schools were used for the study and randomly assigned to the experimental and control groups to be taught using the concrete-representational-abstract strategy and the modified lecture method, respectively. Instruments for data collection included the "Mathematics Achievement Test (MAT) and the Pupils' Dyscalculia Measure (PDM)." Two instructional guides were also used as teaching guides. The reliability of the MAT and the second section of the PDM was established through Kuder-Richardson Formula 21 (KR-21) and yielded a reliability of 0.84 and 0.81, respectively. Cronbach Alpha was used for the second section of the PDM, yielding a reliability of 0.85. Mean and standard deviation were used to answer the research questions, while the null hypotheses were tested at a 0.05 level of significance using Analysis of Covariance (ANCOVA). The findings showed that students with dyscalculia taught with the concrete-representational-abstract had significantly better achievement in mathematics than those taught with the lecture method, and gender did not affect students' achievement. Thus, the concrete representational abstract is effective for teaching students with dyscalculia. It was recommended, amongst others, that the concrete representational abstract should be adopted to teach pupils mathematics in schools, especially those with dyscalculia disability.

Keywords: Concrete-representational-abstract, Dyscalculia, Gender, Modified Lecture Strategy

Introduction

Mathematics is a core field that has shaped man's life in several ways. The field of mathematics has been defined in various ways by various individuals. Hom and Gordon (2021) states that the field is centred on the "logic of shape, quantity, and arrangement." Mathematics is characterised by a broad scope spread across several areas, all of which positively impact life to an extent. It is a fundamental unit in carrying out everyday life activities. It is associated with the growth and development of society throughout history. It exerts an amount of influence and is essential in all fields. It is vital in the context of the economy, finance, and commercial processes, and it is also attributed to facilitating the development of individual cognitive-based skills like problem-solving and higher-order thinking (Bailey, 2017; Frederick-Jonah & Olutu, 2022; Hom & Gordon, 2021).

Considering the innumerable importance of the mathematics field, a good level of understanding and achievement in the subject amongst learners is a matter of utmost importance. However, Stickland (2017) and Idowu (2016) describe mathematics as being difficult for the average learner. Awofala (2017) state that the majority of Nigerian students are unable to express an adequate or comprehensive knowledge of mathematics, leading to underperformance in the subject. The underachievement in mathematics indicates a flaw in the strategy used for mathematics instruction. Mathematics instruction at schools is predominantly carried out through variations (often modified versions) of the lecture method.

The plain lecture method centralises the teacher in classroom instruction, where they are tasked with presenting knowledge to the students, who are expected to learn by passively listening to the teacher and taking down notes (Minghong et al., 2019). Saira and Haffez (2021) state that the lecture method is not particularly effective for meeting learning goals. The issues with the lecture method are attributable to its passive mode of instruction and one-way flow of communication, its inability to engage students' interest and attention, etc. (Abedi et al., 2019; Wei et al., 2017). Some steps have been taken to mitigate the issues of the lecture method, including the use of question and answer sessions, students solving questions on a board, the use of visual instructional aids when explaining concepts to the students, etc.

The lecture method is also not readily adaptable to teach students with specific learning needs, which is likely to exacerbate their further underachievement in mathematics. These learning needs might be psychological, cognitive or behavioural issues. However, this domain is not heavily explored. One such issue is the mathematics-based learning disability

of dyscalculia, a disability that causes difficulties for an individual in understanding and comprehending mathematics effectively in different contexts (Plessis, 2022; Witzel & Mize, 2018).

The way dyscalculia occurs and affects differs from one individual to the next. Six popular forms of occurrence have been highlighted. They include verbal (difficulties in handling mathematics concepts and operations when presented to them verbally), practognostic (difficulties with abstract mathematical concepts), lexical (difficulty in reading and understanding mathematical functions, numerals and operations), graphical (difficulty in writing down mathematical symbols), ideognostical (poor cognition or ability to recall mathematical concepts), and operational dyscalculia (difficulties in performing mathematical operations whether written or spoken) (Galitskaya & Drigas, 2021; Hewapathirana et al., 2021; Miundy et al., 2019). It is notable that this list is not exhaustive and does not cover the entire nature of dyscalculia occurrence, which may occur in unpredictable ways, and there are other ways through which dyscalculia is categorised or sorted.

Symptoms of dyscalculia include deficiency in subitising, difficulty with mental mathematics, understanding time on an analogue clock, difficulty in understanding sequencing with numbers, difficulties in mastering or becoming proficient at choreographed dancing, poor name-to-face recollection, poor understanding of shapes, issues in differentiating right from left, inability to visualise numbers and their functions properly, difficulties with basic mathematical task and operations, inadequate level of retention of mathematics concepts and operations, inability to properly apply learned mathematical concepts to other situations, etc. (Aquil, 2020; Haberstroh et al., 2019; Perini et al., 2020).

There is no universally accepted or acknowledged way to diagnose dyscalculia, so the criteria used for diagnosis tend to vary. Some tools have been commonly employed in diagnosis, and they include standardised tests, surveys, evaluations and reports from teachers, psychological assessments, medical evaluations, etc. (Aquil & Ariffin, 2020; Vogel & Reynolds, 2022). As there exists no medication to manage the appearance of dyscalculia, various interventions have been recommended to be applied in multiple contexts, all of which are geared towards making the mathematics learning process easier for the individual.

Pupils dealing with dyscalculia are at a disadvantage in mathematics learning, a subject that is already deemed complex, even for neurotypical pupils without such disabilities. Thus, considering the limitations of the modified lecture method and its lack of support for learners

dealing with dyscalculia, it becomes necessary to explore other innovative instructional approaches.

The use of a multisensory approach to teaching, multiple representations and manipulatives are all common recommendations for enhancing mathematics learning, particularly for students with dyscalculia. The concrete representational abstract approach to teaching is helpful in this regard, as its framework is comprised of all three of these recommendations.

Concrete-Representational-Abstract (CRA) is an innovative approach to teaching mathematics concepts, which involves moving the learning through three stages of multiple representations, from a concrete experience to abstract skills (Putri, 2019). The three stages involved in the concrete-representational-abstract are in line with the title of the approach and include the "concrete, representational and abstract stages". The concrete stage of the concrete representational abstract is sometimes referred to as the enactive stage. It involves the learner making use of concrete objects (known as manipulatives) in the learning of a mathematical concept. The representational stage, on the other hand, forsakes the use of concrete objects. Instead, learners are made to learn by drawing illustrations and diagrams (usually representations of concrete objects), which are used to aid in their learning of a specific mathematics concept. The abstract level of the concrete-representational-abstract is the final stage that involves what is commonly regarded as traditional and regular mathematics, where the students are guided to learn without the aid of objects or representations, but instead, they are to learn using numbers and symbols (Flores et al., 2018; Morano et al., 2020). The sequence in the concrete-representational-abstract can thus be said to be made up of the "doing", "seeing", and "symbolic" stages. Each stage is built from the previous stage and is supported by the skills and knowledge acquired at the last stage.

To ensure the effectiveness of the concrete-representational-abstract, the teacher ensures the students adequately understand what has been taught at one level of the sequence before attempting to go to the next (Ralphs, 2022). This is necessary, as failure to master learning in any of the stages can facilitate the failure of the whole sequence. The concrete-representational-abstract is also a practical-based approach to teaching; as such, the active participation of the students across all the phases in the sequence is a matter of utmost priority (Ogunleye, 2019). Extra caution and care must also be taken when choosing the object/manipulative to be used at the initial concrete stage, as the success of the stage is dependent on the use of effective tools related to the concept being taught.

The concrete-representational-abstract has been noted for providing a better and more structured way to learn mathematics, enabling and enhancing the learning and mastery of mathematics concepts at different levels, improving the linkage of mathematics concepts to life, developing in the learner the ability to link concrete with the abstract, involves a multisensory and multi-representation approach to learning, enhances active and student centred learning etc. (Florida, 2016; Strickland, 2022). Thus, considering the potential positive implications of using this approach to improve mathematics teaching and learning, it becomes necessary to explore its use in institutions of learning.

The educational experience and outcome of an individual can also be influenced by a number of socio-demographic variables, which exist in the background but hold significant effects on the life experiences of an individual. One such variable is the gender of the individual. The gender variable has a significant influence on the life, perspectives, and experiences of an individual. It is one of the critical underlying frameworks behind the personality and identity of an individual, with its effect cutting across numerous areas, including those related to "cultural, economic, social, political and educational" areas of an individual's life (Frederick-Jonah et al., 2019).

In the educational context, gender is still regarded as an essential area of concern for academic researchers and authorities (Kalpazidou & Cacace, 2017; Owoye & Agbaje, 2016). Frederick-Jonah and Akinsola (2015) assert this, stating that gender's impact on the learning outcomes of students in mathematics and science fields is still highlighted as a point of significant concern and controversy amongst educators. Though some studies have explored gender differences in learning, findings have largely remained inconclusive and tend to vary depending on the context.

Based on all of the above, this study thus explores the use of a concrete representational abstract approach to teaching mathematics to students with dyscalculia while also exploring the moderating effects of gender.

The use of Concrete representational abstract aligns with the principles of experimental learning, a theoretical construct proposed by David Kolb (Thomas, 2022). This theory emphasizes the importance of experience in the learning process. The theory highlights that knowledge is best created through a transformation of experience following a cyclical pattern consisting of "concrete experience, reflective observations, abstract conceptualizations, and active experimentation" (Moorhouse & Jung, 2017). The structured approach in concrete representational abstract mirrors that of the cycle in experiential learning. In line with

experiential learning, in concrete representational abstract, learners first engage with concrete materials and hands on experience, which is followed by representative learning, to bridge their concrete experience with the abstract. Then next comes abstract learning and reasoning, which is structurally similar to abstract conceptualizations and active experimentation. Thus, the theory of experimental learning backs this study

Statement of Problem

Mathematics is one of the most essential fields of study in the world today. However, available reports indicate that it is difficult for the average learner to learn and is characterised by poor achievement rates. underachievement in the mathematics subject has been linked to numerous reasons and variables, out of which issues with the instructional strategy are quite prominent, as the conventional or modified versions of the lecture method commonly used for mathematics instruction might have contributed to this underachievement. Furthermore, the lecture method is not designed to meet the learning needs of pupils with dyscalculia learning disabilities. Thus, there is a need for a more innovative approach to teaching mathematics, one recommendation of which is the concrete-representational-abstract. However, most studies on using this strategy for those with disability focused on small-scale personalised instruction with very few selected students rather than a class or were focused on other forms of disability. Therefore, this study determined the effects of "concrete-representational-abstract on the mathematics (fraction) achievement of pupils with dyscalculia." The study also determined the moderating effects of gender on the dependent variable.

Research Questions

i. What is the the difference in the mathematics mean achievement score of pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method?
ii. What is the difference in the mathematics mean achievement score of male and female pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method?

Null Hypotheses

1. There is no statistically significant difference in the mathematics mean achievement score of pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method.

2. There is no statistically significant difference in the mathematics mean achievement score of male pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method.

Methodology

The study adopted a pre-test and post-test control group quasi-experimental research design. The sample for this study consisted of ninety-eighty (98) pupils in primary six classes in Yenagoa Metropolis, of Bayelsa State. Four schools were selected through purposive sampling techniques. Two of which were randomly assigned to the experimental and control group. Intact classes were used. “Instructional Guide on Concrete-Representational-Abstract Strategy (IGCRAS) and Instructional Guide on Modified Lecture Method (IGMLM) were used as teaching guides while two instruments, Mathematics Achievement Test (MAT) and Pupil's Dyscalculia Measure (PDM), were used for data collection." The IGCRAS and IGMLM were used for the training period for the experimental and control groups, respectively. The MAT was used to measure pupils' achievement in a mathematics topic (fractions). The PDM tested for pupils with the disability and was comprised of a survey session testing for the presence of symptoms of dyscalculia in the pupils and a general basic mathematics test session. The PDM was used along with pupils' academic records in mathematics to diagnose those with the disability. Though it was a whole class intervention, only the results of pupils with dyscalculia are reported in the study. The instruments received validation through expert reviews. The reliability of the MAT and test section of the PDM was established using the Kuder-Richardson Formula (KR-21), which yielded a coefficient of 0.84 and 0.81, respectively. The reliability of the survey section of the PDM was established using Cronbach Alpha, which yielded a reliability of 0.85.

The researcher trained the teachers on implementing the instructional guides during the first week of data collection. The second week was used to identify the pupils with a dyscalculia learning disability. The pre-test was administered to the pupils at the start of the third week, after which treatment commenced and lasted through the fourth and fifth weeks. The students were taught using the instructional guides. The post-test was administered at the end of the treatment. The collected data was analysed using mean and standard deviation for the research question and Analysis of Covariance (ANCOVA) for the null hypotheses.

Results

Research Question One: "What is the difference in the mathematics mean achievement score of pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method?"

Table 1: Summary of Mean and Standard Deviation of Pupils with Dyscalculia Pre-test and Post-test Scores on the Effects of Instructional Strategies on Pupils' Achievement in Mathematics

Instructional Strategies	N	Pre-test Score		Post-test Score		Mean
		Mean	STD	Mean	STD	Gain
CRA	28	18.29	8.39	60.14	12.94	41.85
Modified Lecture	26	16.31	7.50	38.15	8.48	21.84
Total	54	17.33	7.96	49.56	15.57	32.23

Table 1 shows that the post-test mean score of pupils taught through concrete-representational-abstract (M = 60.14, SD = 12.94) is greater than that of pupils taught through the modified lecture method (M = 38.15, SD = 8.48). The mean gain score of pupils taught through concrete-representational-abstract (41.85) is greater than those taught through the modified lecture method (21.84). This indicates that pupils taught through the concrete-representational-abstract had better achievement. Consequently, the ANCOVA was carried out to ascertain if the difference was statistically significant.

Research Question Two: "What is the mathematics mean achievement score of male and female pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method?"

Table 2: Summary of Mean and Standard Deviation of Pre-test and Post-test scores on the effects of Instructional Strategies on Male and Female Pupils Achievement in Mathematics

Instructional Strategy	Gender	N	Pre-test Score		Post-test Score		Mean
			Mean	STD	Mean	STD	Gain
CRA	**Male**	10	18.40	7.59	66.80	13.47	48.4
	Female	18	18.22	9.02	56.44	11.39	38.22
	Total	28	18.29	8.39	60.14	12.94	41.85
Modified Lecture	**Male**	14	14.00	7.48	38.28	8.41	24.28
	Female	12	19.00	6.84	38.00	8.94	19
	Total	26	16.31	7.50	38.15	8.48	21.84
Total	**Male**	24	15.83	7.69	50.17	17.81	34.34
	Female	30	18.53	8.10	49.07	12.81	30.54
	Total	54	17.33	7.96	49.56	15.57	32.23

Table 2 shows that for pupils taught through the concrete-representational-abstract, the post-test mean score of male pupils (M = 66.80, SD = 13.47) was greater than that of female pupils (M = 56.44, SD = 11.39). For pupils taught through the modified lecture method, the post-test mean score of male pupils (M = 38.28, SD = 8.41) was also greater than that of female pupils (M = 38.00, SD = 8.94). The total post-test mean score of male pupils (M = 50.17, SD = 17.81) was greater than the female learners (M = 49.07, SD = 12.81). Consequently, the ANCOVA was carried out to determine if the differences were statistically significant.

Null Hypothesis One: "There is no statistically significant difference in the mathematics mean achievement score of pupils with dyscalculia when taught through the concrete representational abstract strategy and those taught through the modified lecture method."

Table 3: One-way Analysis of Covariance (ANCOVA) of Achievement Scores of Pupils with Dyscalculia Taught through Concrete-Representational-Abstract and the Modified Lecture Method

Source	Type III Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6782.080[a]	2	3391.040	28.523	.000	.528
Intercept	17975.759	1	17975.759	151.200	.000	.748
Pretest	263.560	1	263.560	2.217	.143	.042
Instructional Strategies	6094.461	1	6094.461	51.262	.000*	.501
Error	6063.254	51	118.887			
Total	145456.000	54				
Corrected Total	12845.333	53				

"a. R Squared = .528 (Adjusted R Squared = .509) *Significant at $p < 0.05$"

The result in Table 3 shows that the main effect was significant on pupils' achievement in mathematics ($F_{1,51} = 118.887$, $p < 0.05$, partial eta squared = .501), which gives an effect size of 50.1 percent. Thus, the null hypothesis, which states that "there is no statistically significant difference in the mathematics mean achievement score of pupils with dyscalculia when taught through the concrete representational abstract strategy and those taught through the modified lecture method", was rejected.

Null Hypothesis Two: "There is no statistically significant difference in the mathematics mean achievement score of male and female pupils with dyscalculia when taught through the concrete-representational-abstract strategy and those taught through the modified lecture method"

Table 4: 2 x 2 Factorial Analysis of Covariance (ANCOVA) of Achievement Scores of Male and Female Pupils Taught Mathematics through the Concrete-Representational-Abstract Strategy and Modified Lecture Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7484.000[a]	4	1871.000	17.100	.000	.583
Intercept	17292.198	1	17292.198	158.042	.000	.763
Pretest	275.568	1	275.568	2.519	.119	.049
Instructional Strategies	6695.253	1	6695.253	61.191	.000	.555
Gender	458.438	1	458.438	4.190	.056	.079
Instructional Strategies * Gender	228.595	1	228.595	2.089	.155*	.041
Error	5361.334	49	109.415			
Total	145456.000	54				
Corrected Total	12845.333	53				

"a. R Squared = .583 (Adjusted R Squared = .549), *significant at $p < 0.05$"

The result in Table 4 shows that gender had no significant main effect ($F_{1,49} = 4.190$, $p > 0.05$, partial eta squared = 0.79) or interaction effect ($F_{1,49} = 2.089$, $p > 0.05$, partial eta squared = 0.41). This gives a main and interaction effect size of 7.9 and 4.1, respectively. Thus, the null hypothesis, which states that "there is no statistically significant difference in the mathematics mean achievement score of male and female pupils with dyscalculia when taught through the concrete representational abstract strategy and those taught through the modified lecture method", was accepted.

Discussion of Findings

The findings of the study showed that pupils with dyscalculia had a significantly greater mean achievement in mathematics when taught with concrete-representational-abstract than those taught with the lecture strategy.

This finding agrees with that of Zhang et al. (2021), who explored the "effects of concrete-representational-abstract on the mathematics achievement of students with mathematics learning disabilities" and reported that the concrete-representational-abstract significantly improved the proficiency of the students with the mathematics concepts. The finding also coincides with that of Yakubova et al. (2016), who explored the "use of concrete-representational-abstract sequencing for the teaching of students with autism spectrum disorder" and reported that the strategy was effective. This finding also agrees with that of Milton et al. (2019), who explored the use of concrete-representational-abstract sequence to teach mathematical operations to students with learning disabilities and reported that the use of the strategy had positive impacts on the students' learning.

Interestingly, previous findings indicates there is a consistent positive impact of the concrete representational abstract approach across diverse groups of students with learning challenges, suggesting that this method might address underlying cognitive barriers common to different learning disabilities, and not just dyscalculia.

The success of the strategy for students with dyscalculia might be attributed to the fact that dyscalculic students struggle with abstract mathematical concepts, and the approach bridges this gap by gradually guiding them from tangible, hands-on experiences to abstract reasoning, thereby mitigating this challenge. This gradual transition might have eased cognitive load and improve conceptual understanding, leading to better academic achievement. Also, in adopting the concrete representational abstract approach, the students were allowed more time to properly engaged with the mathematics concept being learned, and were observed to have increased interest in learning activities, particularly when the manipulative were introduced to them. This increased engagement and interest might have further contributed to the study's findings.

The study findings also show that there is no statistically significant difference in the mathematics mean achievement score of male and female pupils with dyscalculia when taught through the concrete representational abstract intervention and those taught through the modified lecture.

This finding agrees with that of Nwabueze et al. (2020), who explored the comparative effects of explicit instruction and concrete representational abstract on explicit instruction on the mathematics achievement of pupils with dyscalculia learning disability and reported that there was no difference in the mathematics achievement of male and female students.

This finding contradicts that of Akinsoso et al. (2015), which explored the use of concrete representational abstract instructional strategy (CRAIS) in the teaching of mathematics and reported that female students significantly outperformed their male counterparts when taught with the strategy. The finding also disagrees with that of Watt-Douglas and George (2021), who explored the impacts of using manipulatives to teach mathematics students and also reported that girls significantly outperformed boys in their mathematics achievement.

This finding indicates that the concrete representational abstract approach is equally effective for both male and female students and no gender-based considerations needs to be made in this context.

While several factors could have contribute to the differing findings from some previous studies, it is particularly noteworthy that the previous study with similar findings on gender differences share key contextual similarities with the current study. Both the current study and the agreeing study were conducted in Nigeria and focused on primary school pupils. In contrast, the studies that reported contradictory findings were conducted outside Nigeria and involved secondary school students. These differences in geographical context, educational levels, and participant demographics may have played a significant role in the variation in results for the study with disagreeing findings. The contrasting settings and age groups likely influenced how gender differences manifested in learning contexts and even in response to the instructional strategies. This highlights the importance of considering contextual factors when interpreting and comparing study outcomes.

Conclusion

It can be concluded that the concrete-representational-abstract significantly enhances the academic achievement of pupils with dyscalculia, and gender did not influence their academic achievement in mathematics.

Recommendations

- Teachers should adopt innovative strategies like the concrete-representational-abstract to enhance mathematics achievement, especially for students with dyscalculia learning difficulties.
- Government and other educational bodies should regularly organise in-service training sessions to equip teachers/instructors with adequate knowledge of educational issues like dyscalculia and how they can be tackled in the classrooms, how innovative approaches like concrete representational abstracts can be effectively applied, etc.

- Government, institutions and other educational stakeholders should ensure the provision of appropriate learning tools, such as manipulatives, for the teaching and learning of mathematics in primary schools.

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